Chapter IX

M-Traffic: Mobile Traffic Information and Monitoring System

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Abstract

Traffic information is crucial in metropolitan areas, where a high concentration of moving vehicles causes traffic congestion and blockage. Appropriate traffic information received at the proper time helps users to avoid unnecessary delays, choosing the fastest route that serves their purposes. This work presents Mobile Traffic (M-Traffic), a multiplatform online traffic information system, which provides real-time traffic information based on image processing, sensor's data, and traveller behaviour models. This system has a modular architecture that allows it to easily be adapted to new data sources and additional distribution platforms. In order to estimate route delay and feed the optimal routing algorithm, a traffic microscopic simulation model was developed, and simulation results are presented. This mobile information service ubiquitously provides users with traffic information regarding their needs and preferences, according to an alert system, which allows a personalized pre-definition of warning messages.

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Introduction

Current advances in mobile communications and positioning systems, as well as the broad use of mobile devices, with increasing functionalities in users' daily life represent new opportunities to extend traffic information systems beyond the traditional information delivered by radio, TV or the Web. Typically, this information is manually maintained by human operators and may not be appropriately updated. None of these information channels are permanently available to users at the moment and at the location they need them. Moreover, they do not provide quantitative data, only available by image or sensor data processing, and they only supply information regarding the current traffic situation; they do not predict traffic conditions for the future.

Mobile Traffic (M-Traffic) is a R&D project developed jointly by YDREAMS (www.ydreams.com), Universidade de Évora (http://www.uevora.pt), and Siemens AG (www.siemens.com), which proposes an advanced technological solution for providing street traffic information. M-Traffic focuses on providing traffic information where and when it is most necessary and making this information available on mobile devices. The proposed solution takes advantage of video cameras in places where traffic conditions are most difficult. Based on these images, the system will provide its functionalities, which go far beyond displaying video information in real-time. Images are processed in order to adapt to various types of devices, which in turn permit the extraction of quantitative and qualitative data about the traffic flow. All the information is geo-referenced in a geographical information system and can be visualised on different devices such as PCs, mobile phones, or PDAs.

Together with the streamed video, M-Traffic offers a set of functionalities suitable for different types of users and appropriate to diverse distribution devices. These functionalities rise from image processing, sensor data, and the use of traffic flow models, which simulate and predict traffic conditions. The purpose of traffic simulation models is twofold. First, it is to estimate the traffic flow and time delay in segments of street network which are not covered by sensors and second, to predict the evolution of traffic conditions. These estimates are the base to routing algorithm.

The system allows users to personalise the service, in order to easily access specific information and alerts. Users may create their own profile, which allows them to receive the information they need as soon as they enter the system.

In the beginning, M-Traffic was thought to be applied in the city of Lisbon, but its modular structure allows its adaptation to be used in any other city with a straightforward task.

This document describes a concrete application of ubiquitous computing technologies to solve a frequent problem faced by users in their everyday life--finding their way through a crowded city.

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Background

In addition to the traditional traffic information services available through on radio and television, several Web sites offer online traffic information. Typically, this information is manually maintained by human operators and may not be appropriately updated. Usually, these services do not provide reliable estimations for the duration of trajectories; they consider just a few points of measure, and they only provide information concerning the current situation, not predicting traffic conditions. Moreover, these services do not ubiquitously provide the information to users, forcing them to search for the data they need.

TrafficMaster (http://www.trafficmaster.co.uk/) provides traffic information services for UK, including live traffic information on World Wide Web enabled devices, map-based congestion information, and a suite of personalised mobile telephone traffic information services, WAP traffic maps, and favourite journey reporting. Traffic information is also made available by AA (Automobile Association), (http://www.theaa.com), where users are able to plan routes, examine traffic conditions, and view incident reports.

Some systems also provide real-time traffic images for traffic conditions monitoring including video streaming. The site of the Instituto de Estradas de Portugal – IEP (Portuguese Road Institute) (http://www.estradasdeportugal.pt) allows the visualisation of streamed video captured by video cameras situated in relevant locations. Vodafone "Trânsito em directo" service (http://www.vodafone.pt/main/funandinfo/alertas/transito/default.htm) allows users to receive alert messages with links to updated images collected by cameras located in the spatial point of their interest. The Advanced Traveller Information System (ATIS) of the New York City Department of Transportation (DOT) provides both streaming video and frequently updated still images from locations in the five city boroughs via the World WideWeb (http://nyctmc.org/) or the City Drive Live on NYC TV, the television network of the City of New York on Channel 74.

The AirVideo traffic service, available by TrafficLand Company, (http://www.trafficland.com/airvideo_intro.php), displays live views from several public traffic cameras on Web-enabled cellular phones. Users can customise cell phone presentations of camera views to display commonly used roadways, as well as alternative routes. TrafficLand currently provides access to over 3,500 live video cameras on its public Web site. More recently, Google Maps (http://www.google.com/gmm/index.html) allows users to search for directions, maps and satellite imagery, and to access real-time traffic information in over 30 major U.S. metropolitan areas directly from Palm OS 5 devices. However, these systems do not consider two main problems--the need for quantitative data, only available by image or sensor data processing, and the necessity of generating appropriate graphic output for the different types of client devices such as mobile phones or PDAs.

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Traffic.com (http://www.traffic.com/index.html) provides users with traffic reports and hotspot alerts for the U.S. via the World WideWeb. Information is gathered from three types of sources: digital traffic sensors; commercial and government partners; and their traffic operations centre staff members, who consistently monitor traffic conditions.

The Mississippi Traffic Watch, powered by the Mississippi Department of Transportation (http://www.mstraffic.com), provides real-time traffic information in 24 of the largest metropolitan areas in the USA. It owns and continues to expand a wireless digital sensor network for collecting traffic and logistics data. From their Web site, users have access to city traffic reports or customise their own city traffic reports in order to receive traffic information by e-mail or telephone.

Inrix (http://www.inrix.com/default.asp) uses Bayesian machine learning algorithms to make statistical inferences and predictions about traffic, based on variables such as weather conditions, construction schedules, holidays, sporting events, and historical traffic patterns. Users will be able to access the technology via partner channels on a variety of devices including smart phones and personal navigation devices, in-vehicle devices, PC desktop applications, Web portals, destination sites, and fleet applications.

The systems mentioned above are mostly traffic information providers; they are not aware of the users' context and they may require the use of specific devices, which reduce their ubiquity.

Circumnav Networks project turns cars themselves into traffic data-collection devices, which then share data wirelessly with other Circumnav-powered cars (http://innovativemobility.org/research/ici/circumnav.pdf). This creates a "social network" of traffic information that all drivers in the network can use to select their routes. The Autoscope system by Image Sensing Systems, Inc., (http://www.autoscope.com/index.htm) provides wide area video vehicle detection by using a high performing microprocessor-based CPU with specialised image processing boards contained in either a camera, box or card format, and software to analyse video images.

Research undertaken at MIT prompted the development of DynaMIT system, which anticipates traffic flow using a database of past conditions and real-time speed measurements and vehicle counts (http://mit.edu/its/dynamit.html) (Ben-Akiva, 1996; Ben-Akiva, 1997). The key to the functionality of DynaMIT is its detailed network representation, coupled with models of traveller behaviour.

Classic approaches to traffic modelling are based either on fluid flow model or on the microscopic behaviour of each car-driver system (Ahmed, 1999; Marques, 2005). Approaches based on cellular automata have also been successfully developed in traffic modelling (Nagel, 1992).

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System Description

The Mobile-Traffic project comprises the conception, design, and validation of a geo-referenced multiplatform online traffic information system, which ubiquitously provides real-time traffic information based on image processing, sensor's data, and traveller behaviour previewing models. M-traffic main features include:

- Automatic detection of abnormal traffic conditions;
- Prediction of traffic conditions based on historical data and current conditions;
- Determination of the best route based on actual or predicted traffic conditions;
- Handling of heterogeneous sources of information;
- Easy customization of the output to different languages and devices;
- Generation of alert messages whenever a specific traffic condition occurs in a pre-defined area defined;
- Dissemination of traffic information among users by SMS or e-mail.

M-Traffic defines a framework that handles data collected by traffic sensors and turns it into usable information for the drivers. Real-time information conveyed by M-Traffic can be accessed any time through the use a large variety of mobile devices such as mobile phones or PDAs. The system is also able to determine the best route between two or more points (allowing the definition of several intermediate points) based on the actual or predicted traffic conditions.

M-Traffic also provides qualitative comparative data. For example, traffic jams are common on several roads in certain periods of time. Users that frequently take a specific route know it, so there is no novelty in telling them so. M-Traffic tells users how traffic conditions are compared with the usual traffic conditions they are familiar with. For each point in space, M-Traffic compares the current data with the data registered in similar conditions and reveals if traffic is more or less congested than usual in those same conditions.

M-Traffic ubiquitously provides users with traffic information regarding their needs and preferences according to an alert system, which allows a personalized predefinition of warning messages. Users can configure the system in order to receive alert messages whenever a specific traffic condition occurs in a pre-defined area. Users can also define a set of locations where they most frequently pass (hotspots), facilitating access to information related to those locations. Moreover, users interacting with the M-Traffic system through mobile phones are able to forward traffic

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Figure 1. Example of an M-Traffic interface screen for mobile phones

information to other users sending SMS or e-mail messages. Figure 1 exemplifies the system's user interface for mobile phones.

Architecture

This system architecture follows the client-server model and is based on several structurally independent, but functionally interdependent modules. Therefore, the system easily can be adapted to new data resources and additional distribution platforms.

The framework needs to be nourished with geo-referenced information from different sources, including:

Traffic Sensors

These are sensors placed along the roads to detect the presence of vehicles and the average speed. There are several types of sensors with the most commonly used being video cameras and loops placed on the asphalt.

User Location

This is the position of the user who is requesting the information. It is used to find the best route from the user's location to another designated spatial point. This

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data can be supplied by a GPS-enabled device, by the mobile phone operator, or simply typed by the user. The location can be an address or a point in geographical coordinates.

Road Graph

The road graph is a representation of the road system covered by the M-Traffic and includes all the information regarding the roads, such as category (e.g., highway, street, round-about), type (e.g., for pedestrians or vehicles), directions (one or two-way), door numbers, turn permissions, and length.

It is used for the calculation of the route between two or more points, to find the geographic position of a point given its address (geo-coding), or to find the closest address given a geographic position (reverse geo-coding).

Maps

Maps are graphical representations of the spatial area covered by the system, used for visualization purposes as the background to show output data to the users and guide them through the physical space. Maps can be aerial photographs or schematic.

Services

Services supply information about geo-located points like restaurants, hotels, gas stations, or pharmacies. The location of these points can be supplied as an address or in geographical coordinates, and can be represented over a map.

The most relevant modules composing M-Traffic system (Fig. 2) are:

- **Sensor data processor:** This module is responsible for collecting the traffic information detected by the sensors.
- **Information system:** This provides the system with statistical and historical traffic data, as well as rules, heuristics and simulation data used to assess and predict the traffic conditions. This module also includes the simulation models and the Traffic Status Generator that holds an updated data structure containing the traffic status information.
- **Alert engine:** This automatically detects abnormal traffic conditions and sends alert messages to the users.

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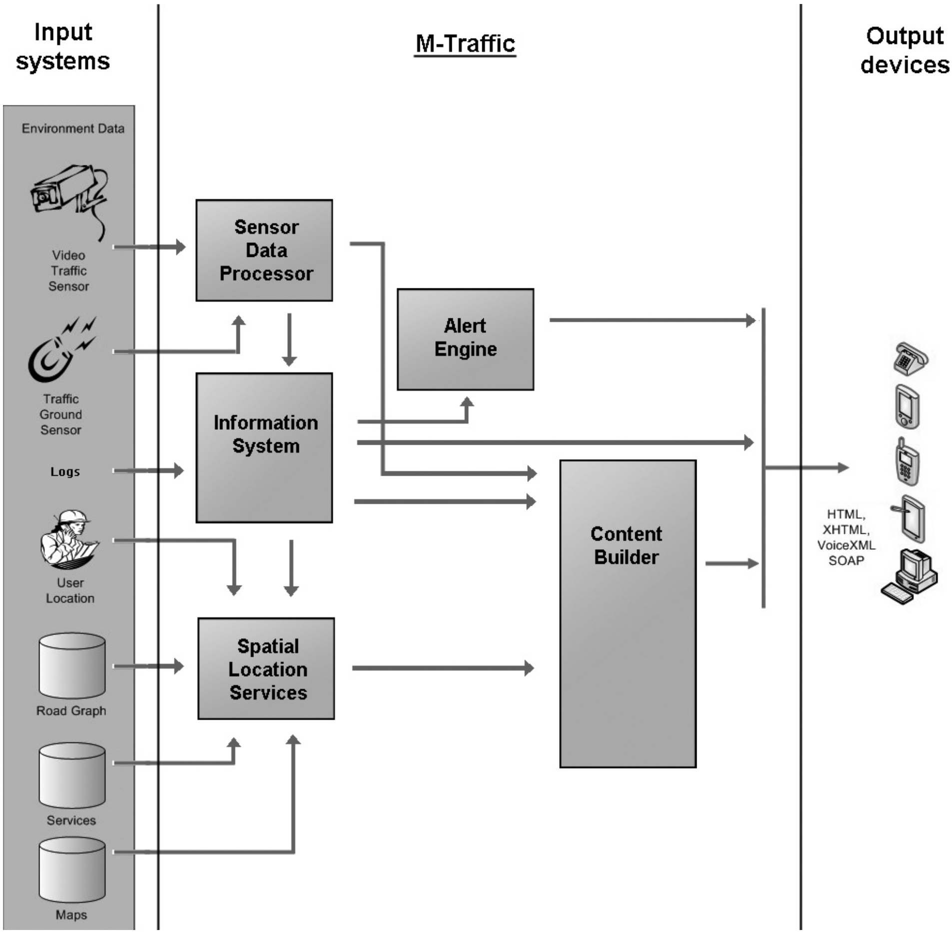
Figure. 2. M-Traffic Architecture



- **Spatial location services:** The main objectives of this module are to allow the real-time determination of users' position, and to calculate the best route between two spatial points.
- **Content builder:** This delivers the information adjusted to the various types of distribution platforms. When this module receives a request, it sends a query to the Information System to select the data related to the area mentioned in the request, formatted according to the characteristics of the device that generated the request.

M-traffic framework was designed to be used by different client applications with their own structure and design. The framework produces XML data that can be transformed into any markup language using XSLT transformation files, while the

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image renders accept several parameters so that the images satisfy both the device and client application requirements.

Sensor Data Processor

The objective of this module is to gather and process the data collected by sensors, and generate, in real-time, the information to nourish the system's database. It can access the sensors directly or query an existing system where this data is stored.

This module comprises several sub-modules, each one responsible for collecting data from one type of sensor (Fig. 3). When video cameras are used, this module includes the Image Processor sub-module to extract quantitative and visual data from images captured by the video cameras. The Image Processor structure comprises the following sub-components (Fig. 4):

- **Image Streamer:** This receives the video signal or files and produces input streams for the Information System, the Image Analyser and Image Producer sub-modules.
- **Image Analyser:** This analyses the video streams produced by the Image Streamer and provides the resulting data to the Information System and the Image Producer sub-module.
- **Image Producer:** This is based on the video streams received from the Image Streamer and the data arriving from the Image Analyser, generates images adjusted to the different devices served by the Content Builder, which are then sent to the Information System.

Figure. 3. Sensor Data Processor module structure. This module can easily integrate several new sub-modules to process data collected by additional different types of sensor.

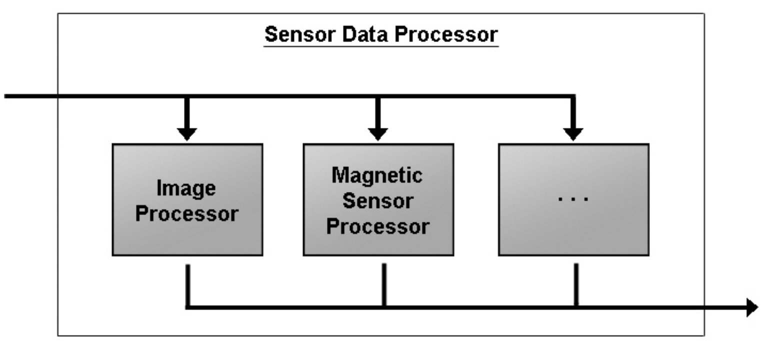

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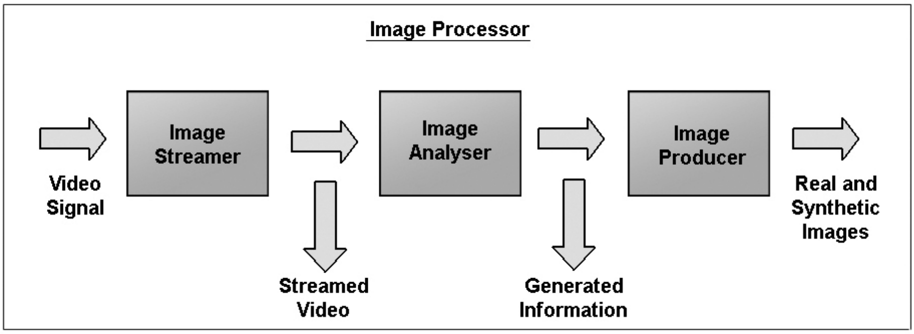
Figure 4. Image Processor components



New sub-modules can easily be added to the Sensor Data Processor in order to allow the system to collect data from new types of sensors.

Information System Module

The M-Traffic information system stores, manages, and provides all the data related to the traffic and the users such as vehicle count, average speed, accident related data, weather conditions, data collected by the Sensor Data Processor module, statistic data, heuristics and simulation data used to assess and predict the traffic conditions, users' personal data, and users' preferences.

Traffic data is stored with an incremental approach, allowing the prediction of future traffic conditions based on the analysis of previous historical data, as well as weather conditions or the occurrence of events that affect the normal traffic flow.

This module includes the Traffic Forecast Engine that, using the collected traffic information and artificial-intelligence algorithms, can predict the traffic status at a given time and place, based on the actual traffic status in the entire road network. It comprises a simulation model for the modelling and analysis of a traveller's behaviour and traffic conditions, which is presented later.

This module also includes the Statistic Engine that processes the real-time traffic data in order to generate statistical information of the traffic conditions. It classifies the traffic conditions according to the period of the day, day of the week, day of the month, and day of the year. Exceptional days like holidays and special event days are processed separately. These statistical data are used by other modules, and also can be displayed to drivers to better plan a trip.

Also, this module comprises the Traffic Status Generator that keeps an updated data structure containing the current traffic status information, which can be seen as a real-time snapshot of the traffic status in the whole area covered by the system.

Figure 5 depicts the structure of the Information System module.

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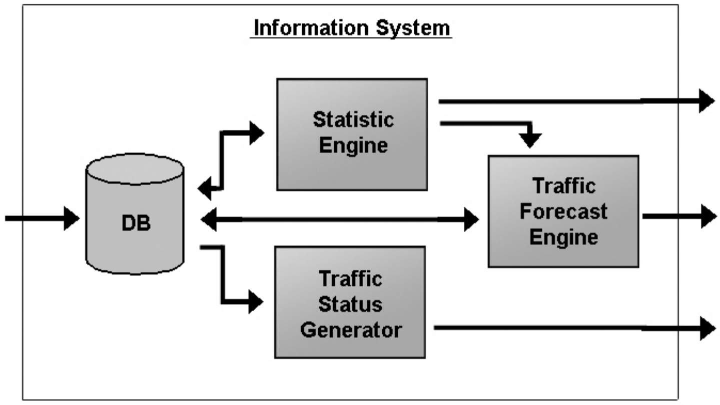
Figure 5. Information System module components



Alert Engine

The Alert Engine allows the system to automatically detect abnormal traffic conditions. It periodically compares the traffic conditions to the statistical values kept by the Information system module and, given some heuristics, checks if the traffic is more or less congested than usual in the same conditions (e.g., same period of the day, same day of the week). If it detects abnormal traffic conditions, an event is generated and alerts are sent to the users according to their profiles and traffic status previews. This module can use the data generated by the Traffic Forecast Engine allowing alerts to be issued ahead of time.

Spatial Location Services

The main objectives of this module are to allow the determination of a user's position in real-time, and calculate the best route between two spatial points. It includes several sub-components (Fig. 6):

- **Geo-coding:** The determines the geographical coordinates of a given address and requires the road information data for the process.
- **Reverse Geo-coding:** This determines the closest address to a given geographical point and requires road information data for the process.
- **Best Route Calculator:** This determines the best route between two or more address points. The calculation depends on the data supplied. It can determine the shortest, the quickest, or the cheapest route and several intermediate stop points can be defined. When supplied with the traffic information, it determines

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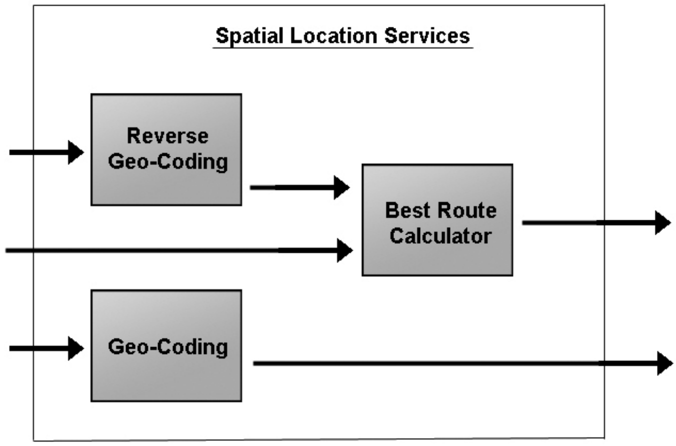
Figure 6. Spatial Location Services module structure



the best route given the actual traffic conditions. When supplied with the traffic forecast information, it determines the best route given the traffic conditions for that moment in time.

Content Builder

This module should support the access to M-Traffic by different mobile devices with distinct characteristics and information processing power.

The ever increasing diversity of mobile devices with diverse technical and functional capabilities (CPU power, display size, interaction paradigms) brings further complications concerning the adaptation and dissemination of content. Content builder is designed to be easily extended to support the use of M-Traffic by additional mobile devices and to provide formatted content including:

- Images generated from a camera captured images overlaid with traffic data, using colour and text (Fig. 7);
- Colour or black and white synthetic images that sketch the traffic conditions in a defined area (Fig. 8);
- Real-time video captured by traffic cameras;
- Textual structured information formatted according to the characteristics of the requesting device.

The content builder structure can be visualized in Figure 9. It comprises several sub-components:

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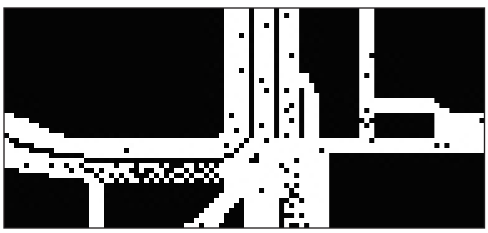
Figure 7. Augmented-Reality image on a mobile phone

Figure 8. Synthetic image of a complex cross showing the traffic intensity



- **Augmented-Reality Image Render:** This generates augmented images from traffic camera captured images superimposed with traffic data, using colour and text. The render gets the current frame from the video system and draws the traffic conditions on it (Fig. 7). The final image is also adapted to the driver's device constraints. For that reason, it is resized, and the number of colours is reduced, if needed.
- **Synthetic-Image Render:** This generates colour or black and white synthetic images that sketch the traffic conditions in a selected area. Synthetic images are simple diagrams that represent graphically the traffic conditions. These images are useful when there is no video system covering the area and can be displayed in the majority of devices.
- **Textual Information Generator:** This structures and formats textual information according to the characteristics of the requesting device.
- **Video Generator:** This produces real-time video captured by traffic cameras.

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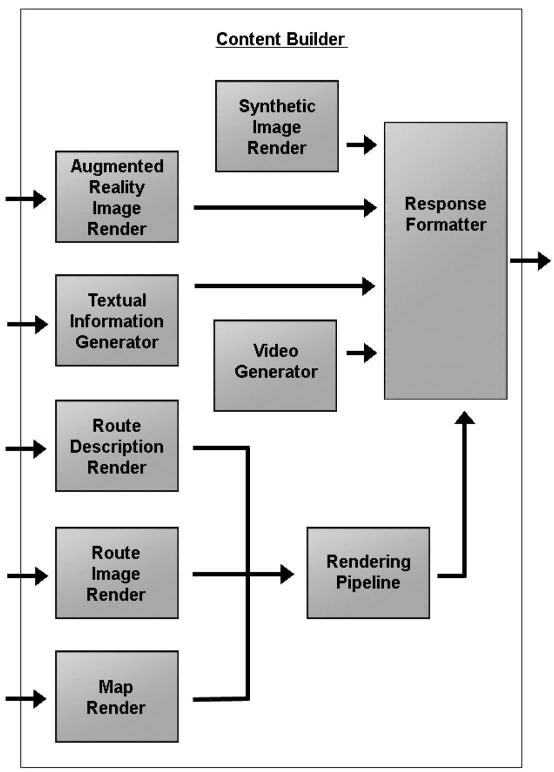
- **Route Description Render:** This processes the best route result, provided by the Spatial Location Services, so that the name of the roads, direction changes, and other useful information are added to it. The output of this module is in XML and, for example, the direction changes are coded as tags instead of text so that it can later be translated into any language and into different output formats using XSLT rules.
- **Route Image Render:** This draws the route so that it can be super-imposed on a map. It gives total control over line colour, style, and width.
- **Map Render:** This generates the background map image, given the geographic coordinates, images size, and source.
- **Rendering Pipeline:** This allows the combination of several layers of images. It gives total control over the layer order, position, size, and opacity. This component also enables the addition of other elements to the image such as legend, copyright notice, and watermark.
- **Response Formatter:** This builds up the request reply according to the network connection and the requesting device.

Figure 9. Content builder module structure



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Traffic Simulator

In order to reply to user requests, the routing service (sub-module of the Spatial Location Services module) must calculate the best route over the graph that represents the street's network in the area covered by the system. However, not every street has sensors (either image or ground sensors). Thus, in order to find minimum time routes, it is necessary to estimate the delay in each street from a simulation model. Apart from image and ground sensor data, the dynamic state of this model can be fed by statistical data and isolated event data. This model aims to describe the behaviour of each car-driver along a predefined route. Thus, a microscopic traffic simulation model was developed.

Model

Classical models for traffic simulation follow either a fluid flow (macroscopic) analogy or an individual car-driver description (microscopic) approach. In spite of being studied since the 50's, only recently the computational power allowed the microscopic simulation approach to emerge as an important tool to study traffic dynamic behaviour. This approach enables the modelling of driver and car characteristics variability.

The model presented in this work has two regimes--a car-following regime and a free-flow regime. These regimes are according to driver behaviours that try to follow the leading vehicle with safety space head way, if it is close enough (less than an upper threshold), or else will drive at a desired speed that depends on the street and the driver. From kinematics laws,

$$\frac{d^2 x_n}{dt^2} = acceleration$$

a car following acceleration dynamic model is defined taking into account: the characteristic street speed; vehicle characteristic parameters; driver perception pure delay; and the driver eagerness to follow the preceding car. The general form of the classical car-following acceleration is

$$action(t) = sensitivity(t - T) \times stimulus(t - T)$$

where t is the observation instant, T is the perception pure delay, $action(t)$ is the acceleration, $stimulus(t)$ is what thrives the driver decision, and $sensitivity(t)$ is a weight put in the stimulus. In this work, the sensitivity is unary and the stimulus

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is the space headway. Nevertheless, a safety distance d_s depending on the vehicle speed is considered,

$$d_s = \alpha \frac{dx}{dt} + d_v$$

where d_v is the vehicle size and α is a constant, which has an effect similar to the sensitivity term.

In this work to model the effect of traffic lights, a threshold distance d_l is considered. If the vehicle is further than d_l from the traffic lights, then those are ignored. Whenever the vehicle is in the traffic light influence area, it responds to the red lights generating a negative acceleration that is calculated such that the vehicle stops behind the traffic light position or another vehicle ahead.

Once the acceleration model depends on two events that may occur independently, the existence of a leading car and the presence of a traffic light, acceleration is the minimum of the two. This amounts to a safety conservative strategy. The final acceleration is saturated in minimum (maximum breaking) and maximum values that are characteristics of the car-driver model.

Simulator Implementation

The simulator is implemented in java. This choice has the advantage of producing portable applications, and the object oriented paradigm is very convenient to implement the main simulator components (vehicles, traffic lights, streets, and sensors) as classes. Furthermore, building a multithreaded implementation allows one to easily parallelise the execution of the simulation whenever multiprocessing may be available.

A configuration input file defines the street graph, the length of each street, the sensor's location, the traffic lights location and temporization cycles, and the car-driver system parameters. The initial conditions are also defined in this file and include a route for each vehicle.

The simulator outputs the position of each vehicle for every sampling time as well as sensor signals that give vehicle counts and average speed at a predefined time interval. These sensor signals correspond to those frequently given by the Traffic Management System. So, this makes it possible to load the traffic status database with data from the simulator and compare the simulator results to measured data. Another goal of the simulator is to test the precision of delay estimates based on average speed which is measured by sensors, though covering only a limited region of the graph.

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Simulation Results

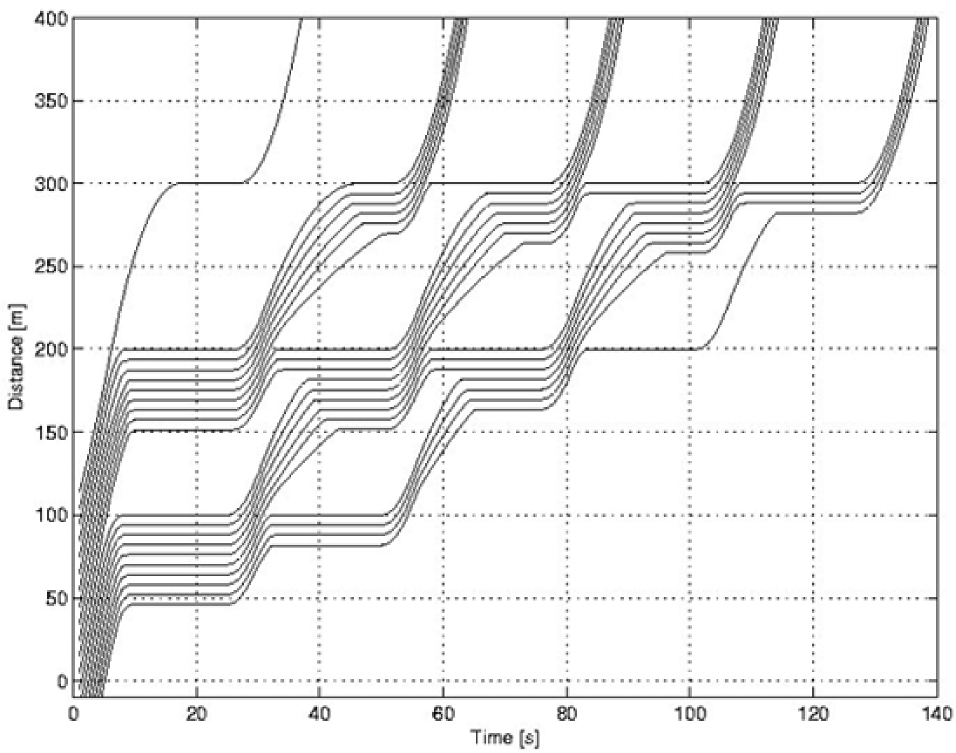
In this section, some results are presented that illustrate the macroscopic vehicle dynamic behaviour in a street segment. The parameters used in the simulations presented below result from a calibration made with just one driver-vehicle system and do not include a parameter variability study.

Simulations were performed using the Euler integration method with a fixed integration time of 1 second.

Figure 10 shows the positions vs. time for each vehicle in a street with three traffic lights. The congestion effect due to the traffic lights at 100, 200, and 300 meters is clear.

Simulation results may be used to test several decisions concerning the M-Traffic system, such as the best place to put the ground sensors or to validate the weighting factor in the graph used by the routing algorithm. The following example concerns the routing algorithm, a sub-module of the Spatial Location Services, which has been implemented using a street's length as a weighting factor in the graph. This

Figure 10. Position of vehicles along the street with traffic lights at 100, 200 and 300 meters



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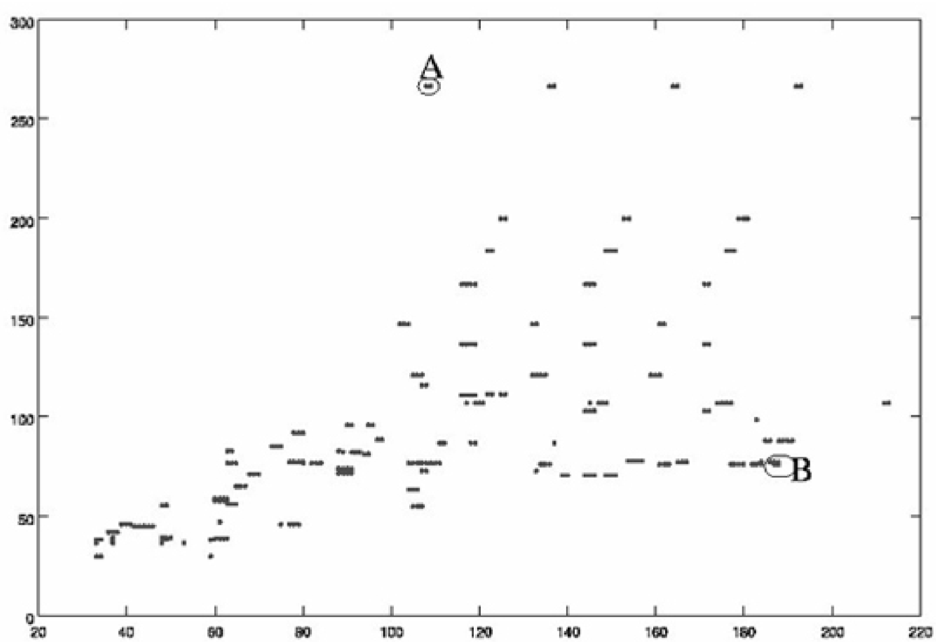
amounts to a minimum path criterium. One goal of the system being developed is to use a minimum time criterium in the routing module. Since there are some streets with sensors that count vehicles and measure speed, it is a natural choice to use the speed information in order to estimate street traffic delay T_{street} .

$$T_{street} = \frac{l_s}{\bar{v}}$$

where l_s is the street length, and $\bar{v}$ is the average speed over a predefined period. Figure 11 shows the result of estimated delay vs. the simulation delay for a wide set of conditions. This simulation use 50 vehicles and covers situations with long queues near the traffic lights, which correspond to streets with high traffic intensity and a short green light period, as well as other situations with very short queues. The temporization cycles, and the location of sensors also vary, representing a broad range of situations. If the estimated time delay was perfectly correlated with the average speed, we would expect to observe a linear relation in Figure 11. It can be seen that when there are queues, the sensor position is critical, and the results have a large dispersion. Estimates that are not in agreement with the "true" delay are due to sensor position. Whenever there are queues near the traffic lights, a sensor located closer to the traffic light indicates a lower average vehicle speed than those located further.

Figure 11. Estimated vehicle delay versus the delay in simulation



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Though there is a correlation between estimated delay and simulation, there are some results quite far from the ideal linear correlation. Results indicated with A in Figure 11 correspond to an over estimated delay. The sensor is located too close to the traffic light in the region that is most affected by the traffic light queue.

Results indicated with B in Figure 11 correspond to an under estimated delay. The sensor is located too far away from the traffic light in a region not affected by the traffic light queue.

This indicates that delay estimates as (1) are not enough to the routing algorithm. Thus, another algorithm should be used to estimate the delay. A more accurate estimate must include other sources of information besides the average speed such as vehicle count in a fixed period of time.

Conclusion

This chapter presents a multi-platform mobile traffic information and monitoring system, which provides real-time traffic information. M-Traffic service ubiquitously provides users with traffic information regarding their needs and preferences, according to an alert system, which allows a personalised predefinition of warning messages. The system is aware of the user's location, providing traffic information and alerts accordingly.

M-Traffic has a modular architecture based on several structurally independent, but functionally interdependent modules. Therefore, the system can easily be adapted to receive and allocate new types of data input (sensors, image, direct logs), and to output data to additional distribution platforms. New sub-modules can be easily added in order to allow the system to collect data from new types of sensors or to provide data to new client devices.

A simulation model is presented and some results are shown. One of the services in this system is a routing service based on a minimum path criterium. In order to change this criterium to minimum time, a delay estimate precision was studied against sensor location. To fully take advantage of the simulation model, it should be calibrated with a statistical sample of driver-vehicle systems, and a set of the most requested routes should be included in the simulator to model travellers' behaviour.

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Future Research Directions

Processing power tends to become so distributed in the environment that computers as we see them today will disappear. New smaller, lighter, and more powerful mobile devices are constantly appearing in the market. These devices allow users to easily access all kinds of information wherever and whenever they need it.

During any decision making process, it is important to have access to relevant data and to be able to anticipate future scenarios. The prediction of future situations can guide users through more appropriate procedure that consequently allow them to achieve better results regarding their established goals. In our particular case of traffic information systems, it is important to accurately preview future traffic conditions, in order to provide users with the best route. Since routes can be large in duration and distance, it is important to know, in advance, how traffic will be in certain location when we will arrive there. It is also important to be able to access traffic information during the whole trip, since traffic conditions may change and we may want to change the route at a certain point.

In the future, we will explore new methods to accurately predict traffic conditions, and innovative visualization techniques and interface procedures that facilitate users' interactions with new mobile devices within a ubiquitous computing scenario.

Acknowledgment

The authors gratefully acknowledge the contribution of National Research Organisation, ADI—Agência de Inovação, project *M-traffic—POSI Action 1.3 Investigação em Consórcio*. Luís Rato has been supported by project FLOW—POSC/EEA-SRI/61188/2004.

References

Ahmed, K. (1999). *Modeling Drivers' Acceleration and Lane Changing Behavior*. Unpublished doctoral dissertation, MIT, MA.

Ben-Akiva, M., Bierlaire, M., Koutsopoulos, H. N., & Mishalani., R. G. (1996, September 9-11). *DynaMIT: Dynamic network assignment for the management of information to travellers*. Paper presented at the 4th Meeting of the EURO Working Group on Transportation, Newcastle, UK.

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Ben-Akiva, M., Bierlaire, M., Bottom, J., Koutsopoulos, H.N., & Mishalani, R.G. (1997). *Development of a route guidance generation system for real-time application*. Paper presented at the 8th International Federation of Automatic Control Symposium on Transportation Systems, Chania, Greece.

Beymer, D., McLauchlan, P., Coifman, B., & Malik, J. (1997). *A Real-time Computer Vision System for Measuring Traffic Parameters*. In *Proceedings of Conference on Computer Vision and Pattern Recognition (CVPR'97*) (pp. 495-501). IEEE Computer Society.

Marques, M. C., & Silva, R. N., (2005). *Traffic Simulation for Intelligent Transportation Systems Development*. In *Proceedings of the 8th International IEEE Conference on Intelligent Transportation Systems*, Vienna, (pp. 320-325). IEEE Computer Society.

Nagel, K., & Schreckenberg, M. (1992). A cellular automaton model for freeway traffic. *Journal de Physique*, *I (*2), 2221-2229.

Additional Reading

Drane, C. R. & Rizos, C. (1998). *Positioning Systems in Intelligent Transportation Systems.* London, UK: Artech House.

El-Rabbany, A. (2006). *Introduction to GPS: The Global Positioning System* (2nd Ed.). London, UK: Artech House.

Greenfield, A. (2006). *Everyware: The dawning age of ubiquitous computing.* Berkeley, CA: New Riders.

Marques, M.C. (2005). *Simulation and control methodologies for distributed traffic management systems*. Unpublished doctoral dissertation (in Portuguese), Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa.

Ogata, K. (2003). *System dynamics* (4th Ed). Prentice Hall.

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